Biological Evaluation of Emerald Ash Borer at Morristown National Historical Park

Prepared By:

Christopher Hayes
Entomologist
&
Heather Smith
Biological Science Technician

USDA Forest Service
Northeastern Area State and Private Forestry
Forest Health Protection
180 Canfield Street
Morgantown, WV 26505

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Abstract

During fall of 2016, personnel from the National Park Service joined Forest Health Protection personnel from the Forest Service, U.S. Department of Agriculture, Northeastern Area State and Private Forestry Field Office in Morgantown, WV, to conduct a survey to detect emerald ash borer (EAB), *Agrilus planipennis* Fairmaire (Coleoptera: Buprestidae), at Morristown National Historical Park (MNHP) in Morristown, NJ. The purpose of the survey was to see if EAB was present and determine the need for management activities. Since EAB has been found near the park and is actively impacting the ash resources, we recommend that MNHP develop a comprehensive ash management plan and that a chemical pesticide treatment plan be put into place to protect high-value ash (*Fraxinus* spp.) trees.

Purpose and Need

The Morgantown Field Office (MFO), Forest Health Protection unit of the USDA Forest Service's Northeastern Area, State and Private Forestry received a request from Robert Masson, Biologist with the U.S. National Park Service, who was concerned about the potential for EAB-caused ash mortality at MNHP. As EAB is currently found within 15 miles of MNHP and the park has extensive ash resources, MFO agrees with the need for

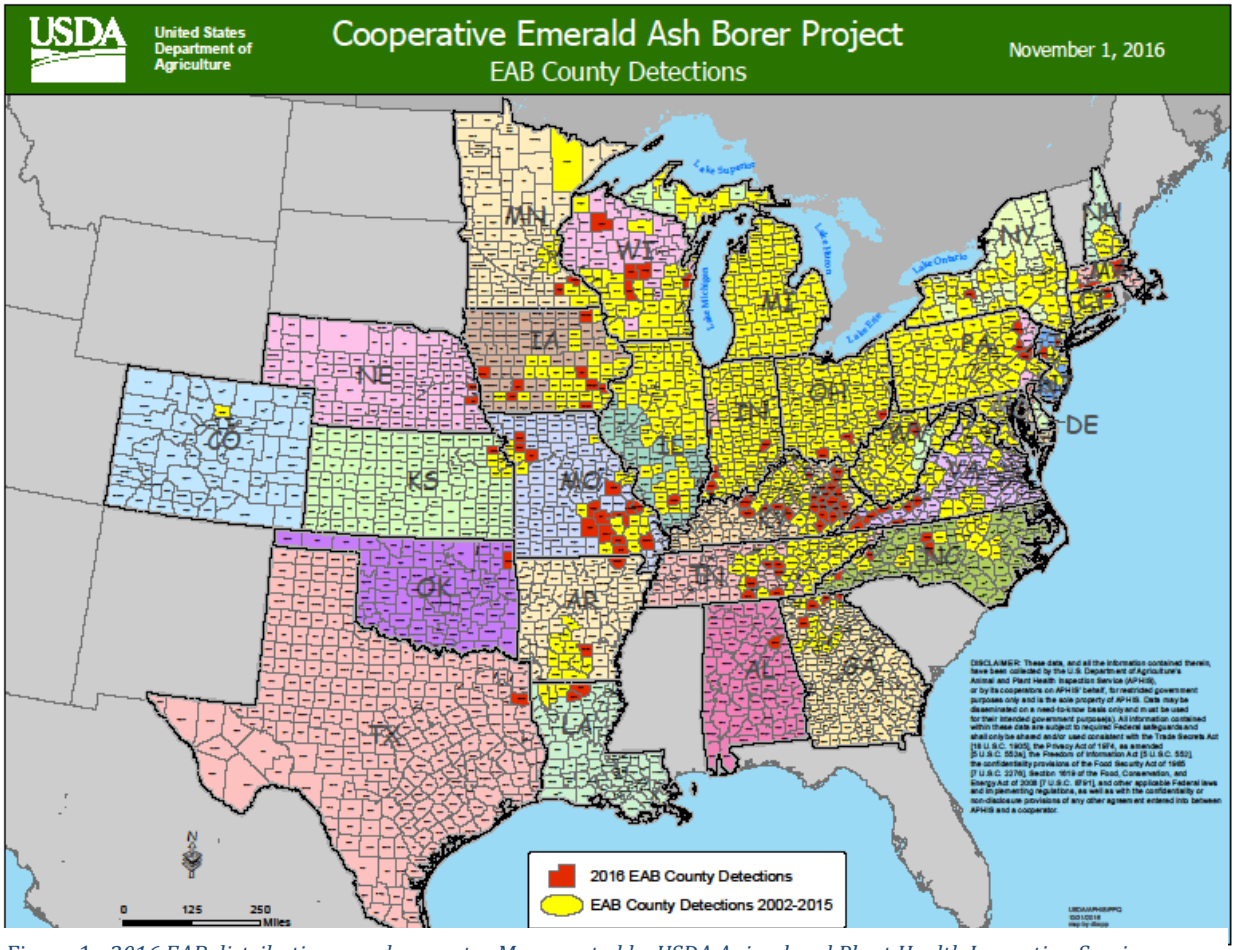

Figure 1. *2016 EAB distribution map by county. Map created by USDA Animal and Plant Health Inspection Service (APHIS)*

MNHP to create an EAB management plan and begin treating trees.

Species Evaluation/Background

Figure 2. *EAB are small metallic beetles: image from Agrilus planipennis Fairmaire Screening Aid. by J.E. Zablotny, USDA APHIS PPQ.*

Emerald ash borer is an exotic, invasive wood-boring beetle native to Eastern Asia (Poland and McCullough 2006) that was first found in North America in 2002 in the Detroit, MI, area and adjacent areas of Ontario, Canada. This aggressive ash killing insect has decimated many forests and as of 2016 has been detected in 30 states including: Alabama, Arkansas, Colorado, Connecticut, Delaware, Georgia, Illinois, Indiana, Iowa, Kansas, Kentucky, Louisiana, Maryland, Massachusetts, Michigan, Minnesota, Missouri, Nebraska, New Hampshire, New Jersey, New York, North Carolina, Ohio, Oklahoma, Pennsylvania, Tennessee, Texas, Virginia, West Virginia, and Wisconsin, as well as Canadian provinces of Ontario and Quebec (Figure 1).

Larvae of EAB feed on ash phloem, causing dieback and eventual tree death and are causing severe mortality in North American ash (Tluczek et al. 2011). Green, black, white, and blue ash have all been killed by EAB and, additionally, white fringetree (*Chionanthus virginicus*) has now been found to be attacked by EAB (McCullough et al. 2015). Emerald Ash Borer impacts all diameter classes of ash and kills both healthy and stressed trees within 3 to 5 years of their becoming infested (Siegert 2012).

EAB has a one or two-year life cycle. Adult beetles are slender, elongate, and bright green and emerge in spring. Newly emerged adults feed on ash leaves causing negligible damage and, after a few days of feeding, mating occurs. After additional feeding that may last up to two weeks, females lay their eggs individually in bark crevices or under bark flaps on the truck or branches of ash trees. Eggs hatch after 7-10 days and newly hatched larvae chew through the bark and into the phloem and cambial region of the tree where they feed on phloem for several weeks. Feeding larvae create serpentine shaped galleries that are packed with fine sawdust-like frass in the inner bark; their feeding often causes etching of the outer sapwood.

Larvae pass through four instars as they feed and then in autumn they excavate a shallow chamber in the sapwood in which they overwinter in a pre-pupal larval stage. Pupation occurs in late April or May and newly formed adults remain in the pupal chamber or bark for one to two weeks before emerging through small (3-4 mm), D-shaped exit holes (Figure 3).

Figure 3. *Characteristic D-shaped emergence hole left by EAB on a green ash tree*

Many ecological damages associated with the loss of ash from North American forests may be expected. The number of faunal species that utilize ash is large; many species are dependent on ash, utilizing ash exclusively. A recent study of

our knowledge of arthropods that use ash found 282 native species associated with North American ash, 43 of which feed exclusively on it and would be at a high risk for endangerment with the loss of ash (Gandhi and Herms 2010). Ash trees also provide food and habitat for several bird and mammal species (Faanes 1984, Rumble and Gobeille 1998) and contribute to nutrient cycling in hardwood forests (Reiners and Reiners 1970).

Project Location/Description

Early in 1777 and in the harsh winters of 1779-1780 General George Washington's Continental Army was encamped in northwestern New Jersey at Morristown where the young army was retrained and restructured during the American Revolutionary War. This is the site of MNHP today. New Jersey was a central location within the American Colonies, making Morristown a strategic point for the troops, as it was a steady travel intersection during the war. The park is located about 40 miles west of New York City and spans just over 1700 acres.

The park's forest composition is of northern red oak (*Quercus rubra*), white oak (*Quercus alba*), along with other deciduous and coniferous tree species. The forest is split up into blocks by trails, roads, and mowed fields. Past land use was for cultivation, grazing, and logging, and many areas have been repeatedly cut. Today the forest reflects these clearing activities and some of the areas exist now as successional forests. Historically, American chestnut (*Castanea dentata*), oak species (*Quercus spp*), and hickory species (*Carya spp*) were dominant before anthropogenic disturbance.

The species composition of the forest reflects the clearing practices and deer browsing pressure of recent times – seen in the presence of Tuliptree (*Liriodendron tulipifera*) and American beech (*Fagus grandifolia*) as dominants in the forest canopies of some cover types. Tuliptree is a major component of the most common cover types in the park. Other woody species dominant (depending on cover type) in the current forest are: Sweet birch (*Betula lenta*), American hornbeam *(Carpinus caroliniana*) , Black locust (*Robinia pseudoacacia*), White oak (*Quercus alba*), Red oak (*Quercus rubra*), American witchhazel (*Hamamelis virginiana*), Sugar maple (*Acer saccharum*), Red maple (*Acer rubrum*), Flowering dogwood (*Cornus florida*), Black oak (*Quercus velutina*), Maple-leaved viburnum (*Viburnum acerifolium*), Black cherry (*Prunus serotina*), White Ash (*Fraxinus americana*), Green ash (*Fraxinus pennsylvanica*), Black ash (*Fraxinus nigra*), Hophornbeam (*Ostrya virginiana*), Spicebush (*Lindera benzoin*), Japanese barberry (*Berberis thunbergii*), Multiflora rose (*Rosa multiflora*), Mockernut hickory (*Carya tomentosa*), Black huckleberry (*Gaylussacia baccatta*), Chestnut oak (*Quercus prinus*), Yellow birch (*Betula allegheniensis*), Eastern poison ivy (*Toxicodendron radicans*), and Pignut hickory (*Carya glabra*). Ash is a minor component of many of the forest cover types and a major component of a few forest cover types.

The exotic, invasive Japanese barberry is a dominant shrub in these forests today. Other non-native invasive shrubs/herbaceous species in the forest edges and posing a threat

to the native plant species diversity and regeneration in the park are: Privet (*Ligustrum vulgare)*, Wineberry (*Rubus phaenicolasius)*, Winged burning bush (*Euonymus alatus)*, Japanese stiltgrass (*Microstegium vimineum)*, Multiflora rose (*Rosa multiflora)*, Japanese honeysuckle (*Lonicera japonica)* and Autumn olive (*Elaeagnus umbellata)*. These non-native invasive species should be monitored and controlled in order to keep them from spreading in the landscape and outcompeting the native flora which includes any regenerating ash and other native tree seedlings.

Project Objectives

The objectives for this evaluation were to 1) determine whether EAB was present at MNHP, 2) assess the location and health of ash trees within the park, and 3) assess the practicality for various management activities to protect and maintain the ash resources.

Project Methods

On October 20, 2016 Chris Hayes, Entomologist, and Heather Smith, Biological Science Technician, of the USDA Forest Service met Robert Masson, Biologist at MNHP to look for evidence of EAB presence and to identify ash trees and assess practicality of various management options for maintaining ash trees into the future at MNHP.

MNHP covers over 1,700 acres, of which most are forested and contain white ash found scattered and in pockets throughout the park.

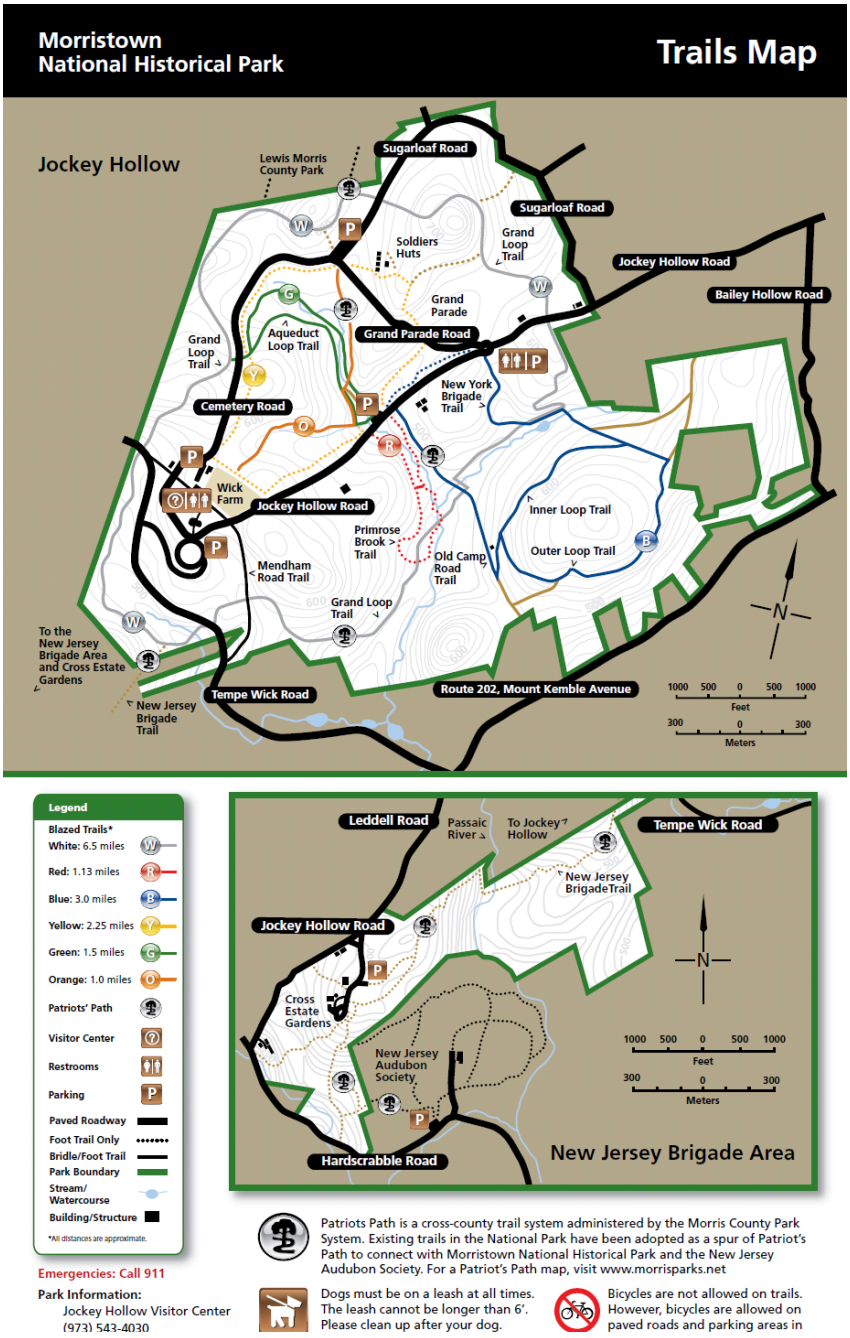
Morristown
National Historical Park
Trails Map
Jockey Hollow
Lewis Morris County Park
Sugarloaf Road
Soldiers Huts
Grand Loop Trail
Jockey Hollow Road
Bailey Hollow Road
Grand Parade
Grand Parade Road
Aqueduct Loop Trail
New York Brigade Trail
Cemetery Road
Wick Farm
Primrose Brook Trail
Inner Loop Trail
Outer Loop Trail
Mendham Road Trail
Old Camp Road Trail
To the New Jersey Brigade Area and Cross Estate Gardens
New Jersey Brigade Trail
Tempe Wick Road
Route 202, Mount Kemble Avenue
Feet
Meters
Legend
Blazed Trails*
White: 6.5 miles
Red: 1.13 miles
Blue: 3.0 miles
Yellow: 2.25 miles
Green: 1.5 miles
Orange: 1.0 miles
Patriots' Path
Visitor Center
Restrooms
Parking
Paved Roadway
Foot Trail Only
Bridle/Foot Trail
Park Boundary
Stream/ Watercourse
Building/Structure
*All distances are approximate.
Emergencies: Call 911
Park Information:
Jockey Hollow Visitor Center
(973) 543-4030
Leddell Road
Passaic River
To Jockey Hollow
Tempe Wick Road
New Jersey BrigadeTrail
Jockey Hollow Road
Cross Estate Gardens
New Jersey Audubon Society
Hardscrabble Road
New Jersey Brigade Area
Patriots Path is a cross-county trail system administered by the Morris County Park System. Existing trails in the National Park have been adopted as a spur of Patriot's Path to connect with Morristown National Historical Park and the New Jersey Audubon Society. For a Patriot's Path map, visit www.morrisparks.net
Dogs must be on a leash at all times. The leash cannot be longer than 6'. Please clean up after your dog.
Bicycles are not allowed on trails. However, bicycles are allowed on paved roads and parking areas in

Figure 4. *Morristown NHP official trail map including the Jockey Hollow and New Jersey Brigade Areas.*

Because there are more ash trees than we would be able to treat or to inventory we prioritized ash trees for inventory into four areas: trees around developed areas (visitors center, parking lots, etc.), adjacent to roads, adjacent to trails, and in wooded areas.

It was determined that the Jockey Hollow Visitor's Center and Wick Farm and their parking areas were the highest use areas. On the day of our site visit we were able to inventory and assess all the trees within 100 feet of the structures and parking areas of the Jockey Hollow Visitor's Center and Wick Farm. For each ash tree, we recorded a GPS point, measured diameter at breast height and visually inspected the tree for evidence of EAB infestation (exit holes, branch dieback, galleries in inner bark, and/or bark cracking). To get a general idea of the numbers of ash trees along the roads we slowly drove the roads of the Jockey Hollow section of the park.

We recommend that areas within 100 feet of the roads within the park be inventoried for ash trees. As this is a fairly large area, the park may choose to only GPS and flag these ash trees and not do a full assessment unless personnel are available to do this work. Ash trees along trails are also of concern, but as there are many miles of trails inventorying these trees may not be practical.

Results

Our inventory of the area surrounding the Jockey Hollow Visitor's Center and Wick Farm found 93 ash trees within 100 ft. of a target (a structure, a high-use foot path, or a parking spot)(Figure 5). These trees ranged from 7-37 inches in diameter (at breast height) and had an average diameter of 17.6 inches and were mostly white ash. These ash trees made up a large proportion (approximately 50%) of the trees in the Jockey Hollow Visitors Center area, and their loss would very much change the character of this area. These trees make up a portion—perhaps half—of the trees that will need to be inventoried at developed sites at MNHP and considered for removal or treatment. The trees are in what we consider the high priority area, that is, around developed sections of the park. Allowing these trees to be killed by EAB and not removing them is not recommended in areas open to park guests. Other developed areas that need to be inventoried for ash trees include the three additional parking areas in Jockey Hollow, the Soldiers Huts, Guerin House, Cross Estate Gardens, and the other developed areas of New Jersey Brigade Area, Fort Nonsense, and Washington's Headquarters.

The order of priority for the rest of the park would be ash trees near roads, then near trails, and finally those trees in forested lands. Monitoring and inventorying all the ash trees in these areas may not be feasible. Ash trees within 100 feet of roads, however, will need to be accounted for. A general inventory of ash near the roads will also be important as MNHP may choose to hire a logging company to fell or fell and remove these trees.

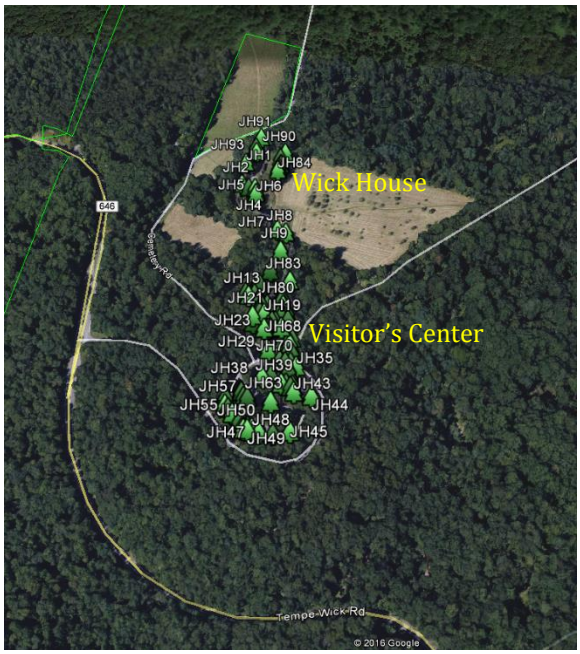

Figure 5. *Trees inventoried for consideration for treatment or removal around Jockey's hollow Visitor Center and Wick House at MNHP*

Discussion

MNHP has extensive ash resources that are spread out throughout the park. Our limited inventory of ash trees did not find any evidence of EAB, but that does not mean EAB is not present in MNHP. Initial attacks are in the tops of trees and are notoriously hard to detect. Since EAB has been caught in Bridgewater Township within 10 miles of the park, it is recommended to begin treating trees that are to be protected from EAB. The general recommendation (Herms et al. 2014) is to begin treating ash trees once EAB is within 15 miles, so now is the time to develop an EAB management plan and to begin treating trees. Alternately, a monitoring program consisting of trapping and observations could be started to confirm the presence of EAB in MNHP.

The park will only be able to protect ash trees that they actively treat with pesticides. In areas of southeast Michigan where EAB was first found, ash mortality in forest stands is nearly 100% (Gandhi et al. 2008). Although there are EAB management tools—chemical and biocontrol for example—that offer some ability to protect ash trees, these tools have distinct limitations; it is not practical or even advisable to treat every ash tree with pesticides and biocontrol is still in the early, experimental stages. There is some question as to the extent of the impact on EAB populations these parasitic insects will have. Efforts to breed EAB resistance into ash stocks are ongoing (Koch et al. 2012), but breeding ash trees for EAB resistance will likely take many years. So for all practical purposes, an EAB management plan at this time consists of deciding which ash trees will be able to be protected with pesticides and deciding how to deal with all the standing dead ash trees that are created in the coming decade. In addition, there is the possibility of participating in biocontrol release programs.

When EAB arrives in an area it starts attacking ash trees in the upper branches, causing branch dieback at first, but soon begins killing trees and can cause near complete mortality of all mature trees within six years (Knight et al. 2012).

When ash trees die, they rapidly become brittle, are prone to breakage, and become dangerous to remove. In some cases, chemically treating for the remaining life of a tree may cost less than removal, especially if the removal is too costly or too dangerous to the remover (Liu and Miller 2014). Because of the large number of ash trees that will die with the establishment of EAB in MNHP, it is important to develop an ash tree removal plan to reduce the number of standing dead trees and to stagger the cost of tree removal over time. MNHP may choose to develop this snag removal plan using the priority areas suggested in this report. That is, prioritize trees for felling or removal dependent on which area it is in, with trees that will not be treated with pesticides and near developed areas first for removal and, at the other end of the spectrum, let dead ash trees in forested areas away from roads and trails fall naturally.

Ash trees are common throughout MNHP, but are rarely the dominant tree species. Dead ash trees will cause extensive small-scale disturbances. In some areas, when individual ash trees die shade-tolerant species will benefit. This is the case for most of the park and large-scale loss of forest cover is not to be expected. Therefore, reforestation activities should not be anticipated. Loss of ash trees will have implications for the current deer management plan being developed and

should be incorporated into that planning document.

Any forest understory re-plantings that you may choose to do will require protection from herbivores, such as deer and rodents, and invasive plant species competition, until the new plantings are well established. In some areas of EAB infestations, a small number of ash trees have been observed to be surviving EAB infestation. These trees may have some natural resistance to EAB and could provide the genetic material for the next generation of ash trees.

Management Options

No Action

If no action is taken, EAB will be allowed to infest all ash trees within MNHP. In this case, it is likely that close to all ash trees would eventually be killed by EAB. Although most other treatment options would also result in a loss of most ash in the park, there would likely only be ash seedlings after the initial mortality period (i.e., the six years in which EAB would kill most all ash trees). After the initial mortality event that kills most ash it would be advantageous to have protected some of the trees that will help in future management activities aimed at preserving and reestablishing ash trees.

Chemical Insecticide

Ash trees can be treated with chemical pesticides that kill EAB as they attack treated trees. Types of pesticide treatments include systemic basal trunk sprays, soil-applied systemic insecticides, trunk-injected systemic insecticides, and protective cover sprays (Herms et al. 2014).

Trees should be treated with pesticides before EAB has caused extensive damage to a tree. An accepted level of crown dieback for pesticide treatment is 30% dieback or less, while also taking into consideration any other defects such as decay or poor form. Sometimes 31-60 % crown dieback may be acceptable if the tree is of very high value. However, any tree with greater than 50% dieback cannot be expected to survive even after treatment (Herms et al. 2014). Ideally, a tree should be treated when there is a local EAB threat and prior to the tree sustaining damage.

There are a number of considerations to make when deciding which pesticide to use. Although ash trees are wind pollinated, impacts to pollinators and other non-target insects should be considered. Some of the chemicals used in various pesticide treatments are highly toxic to aquatic vertebrates and their application should be avoided when soils are water saturated or when drift may settle on bodies of water. Injected systemic insecticides are often chosen because there is no associated drift with this treatment. Soil injections and drenching do not have drift issues either, but care should be taken to avoid these treatments when soils are water saturated. Pesticide labels include information on toxicity to non-target organisms and precautions that need to be taken so always consult pesticide labels for detailed instructions.

Most pesticides listed for use on EAB are restricted-use pesticides, meaning they can only be applied by a certified pesticide applicator. There are, however, a few products that can be used for EAB that are not restricted use (Table 1). Consult your state agencies for registration information.

Although we do not want to endorse one particular product or treatment, we would like to discuss some of the benefits and drawbacks of particular treatments.

Soil Applications

Drenching and soil injections are convenient treatment methods and products are available that require a certified applicators license and some that do not. These application methods require little to no specialized equipment to apply. Products for drenching and soil injections typically use imidacloprid or dinotefuran. Soil injections of imidacloprid should be made 2-4 inches below the soil surface for good root uptake, as it can bind to organic materials in the top soil layers. For larger trees and when EAB population levels are high it is suggested that chemicals should be applied at the highest application rate, but care should be taken not to exceed the per acre limitations stated on the label.

Protective Cover Sprays

Protective cover spray is another method for protecting trees from EAB and other wood boring and bark beetles. Typically, the entire trunk of the tree is sprayed with pesticide, but since EAB attack smaller branches the entire tree must be sprayed for EAB treatments. There is considerable drift associated with this type of treatment in which chemicals land on unintended targets. Also, this treatment does not kill EAB that is already within the tree. Chemicals used for protective cover sprays include permethrin, bifenthrin, cyfluthrin, and carbaryl.

Trunk Injections

Trunk injections have many benefits but require specialized equipment and considerable expertise to apply. With this method, it is much easier to avoid the drift associated with protective cover sprays or the water runoff potential of soil injections and drenching. Also, uptake of chemicals is faster in truck injections than in soil applications (Herms et al. 2014). Truck injection involves drilling holes through the bark and sapwood at the base of the tree causing wounds to the tree which may become a concern if a tree needs repeated treatments. Formulations of azadirachtin, emamectin benzoate, and imidacloprid are used for truck injections. Trunk injection of emamectin benzoate in mid-May or early June provides consistent control of EAB, and can provided multiple years of protection (up to 3 years)(Smitley et al. 2010). A natural product, azadirachtin, is also available formulated as TreeAzin™, which is injected into the trunk of the tree as a systemic treatment. This product is a natural tetranortriterpenoid compound extracted from the seed kernels of neem (*Azadirachta indica*) (Fares et al. 1980).

Much care and consideration should be taken when choosing which trees to treat as chemical treatments are labor intensive and costly. It may not be fiscally possible to keep retreating all the trees you would ideally like to save, as multiple treatments to each will be required to get through the initial wave of mortality.

MNHP may want to treat trees in a forested setting with chemical treatments. In this case the following approach may be implemented: select at least 10 good specimen trees (e.g. dominant, healthy, good seed producers) at a sex ratio of at least 5:1 (females: males) and treat every 1-3 years, depending on the pesticide selection and local EAB densities. With this management technique you may be able to preserve the trees of both sexes required for pollination and preserved genetic diversity in a selected forested area.

Table 1. *Insecticides used to protect ash trees from emerald ash borer attack. This is not an exhaustive list. Pesticide registration varies by state, so always consult your state prior to use to confirm that a specific production is registered for use in that state. Table taken from Herms et al. 2014*

Insecticide Formulation	Active Ingredient	Application Method	Recommended Timing
Products Intended for Sale to Professional Applicators			
Merit® (75WP, 75WSP, 2F)	Imidacloprid	Soil injection or drench	Early to mid-spring or mid-fall
Safari ™ (20 SG)	Dinotefuran	Soil injection or drench	Mid- to late spring
Transect ™ (70WSP)	Dinotefuran	Soil injection or drench	Mid- to late spring
Xylam® Liquid Systemic Insecticide	Dinotefuran	Soil injection or drench	Mid- to late spring
Xytect™ (2F, 75WSP)	Imidacloprid	Soil injection or drench	Early to mid-spring or mid-fall
Azasol™	Azadirachtin	Trunk injection	Mid- to late spring after trees have leafed out
Imicide®	Imidacloprid	Trunk injection	Mid- to late spring after trees have leafed out
TREE-äge™	Emamectin benzoate	Trunk injection	Mid- to late spring after trees have leafed out
TreeAzin®	Azadirachtin	Trunk injection	Mid- to late spring after trees have leafed out
Safari™ (20 SG)	Dinotefuran	Systemic bark spray	Mid- to late spring after trees have leafed out
Transect (70 WSP)	Dinotefuran	Systemic bark spray	Mid- to late spring after trees have leafed out
Zylam® Liquid Systemic Insecticide	Dinotefuran	Systemic bark spray	Mid- to late spring after trees have leafed out
Astro®	Permethrin	Preventive trunk, branch, and foliage cover sprays	Two applications at 4-week intervals; first spray should occur at 450-550 degree days (50°F, Jan.1); coincides with black locust blooming
Onyx™	Bifenthrin		
Tempo®	Cyfluthrin		
Sevin® SL	Carbaryl		
Products Intended for Sale to Homeowners			
Bayer Advanced™ Tree & Shrub Insect Control	Imidacloprid	Soil drench	Early to mid-spring
Optrol ™	Imidacloprid	Soil drench	Early to mid-spring
Ortho Tree and Shrub Insect Control Ready to Use Granules®	Dinotefuran	Granules	Mid- to late spring

Biological Control

Parasitoid wasps, including three gregarious larval endoparasitoid species (*Spathius agrili, Spathius galinae,* and *Tetrastichus planipennisi*) and a solitary parthenogenic egg parasitoid (*Oobius agrili*) are available for release against EAB through the USDA APHIS EAB Biological Control Program. Guidelines have been prepared and recently updated on site selection, and methods for release and recovery (USDA-APHIS/ARS/FS 2016).

It is important to understand that the release and establishment of EAB natural enemies is not likely to provide any short-term control of EAB. Biological control is a long-term approach that is still experimental and will likely require a complex of natural enemies to maintain EAB below damaging levels. Currently, research into the success and establishment of these biocontrol agents is ongoing (e.g., see Jennings et al. 2016). It is hoped that with the long-term management tools of biological control and breeding natural resistance into ash trees that we will be able to reestablish ash on a landscape scale in the future in areas that have experienced dramatic ash losses.

Management Alternatives

Alternatives

Alternative 1 - No action.

Alternative 2 – Protect select ash trees with chemical pesticides and remove ash trees along road and other areas where dead ash will become hazard trees.

Recommendations

We recommend that MNHP develop a comprehensive ash/forest management plan that includes a chemical suppression/protection treatment plan and a hazard tree removal plan. Select ash trees for treatment with < 30 percent decline in developed areas. The reason we suggest treating ash trees in developed areas is that treatment will be less expensive than removal of trees next to structures and loss of these trees will have high impact of character of the most highly visited areas of the park. MNHP may choose, however, to protect a group of trees in a wooded area with the objective of preserving a genetically viable group of trees within the park.

Because MNHP has more ash trees than are practical to treat a decision will be made for which trees to protect. It should be assumed that in about six years all the ash trees within the park that are not treated will be dead. Because most of these trees are away from any roads and developed areas, leaving them as snags and to fall at their own rate may be acceptable. MNHP may choose to create a buffer around roads. This could be done by felling all ash trees within 100 feet of roads. These trees could be left on the ground or removed. Depending on local markets, this timber could also be sold. The value of this timber could offset the cost of management activities depending on the market and park policies on timber sales.

Ash trees within MNHP are scattered, grow in small groups, or are dominant in limited areas. With the death of these trees, small forest openings may be created. The canopies of nearby trees will grow and soon fill in small openings. In some cases, however, larger openings will be created. This does not appear to threaten to cause large-scale deforestation, but impacts of non-native, invasive species should be considered. There will be more growing space for understory plants and, because the understory plants are

dominated by non-native invasives, MNHP should consider developing an eradication program with the objective of restoring native plant communities.

Biological control releases should also be considered if there is no conflict with the Park's management plan. Biocontrol agents are now being released experimentally. There is potential in the long term that a combination of biocontrol and introduction of genetically resistant ash trees enable land managers to successfully reestablish ash trees into our forest sometime after the initial wave of mass ash mortality.

In addition, we recommend that MNHP begin a public awareness campaign about EAB and continue to monitor tree health conditions and survey for signs and symptoms of EAB. In addition to visual surveys, we recommend deploying attractant-baited traps to survey for low level infestations of EAB. The MFO can assist on preparing a monitoring plan for trapping (e.g. quantity, trap type, trap locations, etc.), and can help prepare a display to place in their visitor center that explains their EAB management plan.

We recommend Alternative 2 based on the following considerations:

1) This alternative protects high-value ash trees in high-use areas and helps maintain the character of the park.
2) We also recommend releasing available EAB parasitoids in infested areas away from chemically treated trees, if this does not conflict with the Park's management plan. The establishment of these natural enemies is experimental, but may offer the opportunity for long-term control and may minimize the need for repeated, ongoing chemical treatments.

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